Shelterwood Systems in South-Central Oregon: an Examination of Natural Regeneration Knowledge

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A report to the Forest Supervisors of the
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EXECUTIVE SUMMARY

This report summarizes natural regeneration knowledge relevant to the Pacific Northwest, with particular attention to south-central Oregon. Excessive reforestation costs and work force limitations led to this re-examination. A reference document from which to shape future management direction is provided. Answers to technical questions are contained in the SELECTED ANNOTATED BIBLIOGRAPHY OF NATURAL REGENERATION AND SHELTERWOOD SYSTEMS LITERATURE (electronic), the first comprehensive shelterwood bibliography since 1965. Investigation consisted of literature review and tutorial studies at the University of Washington during winter, 1985.

Most reforestation regimes in south-central Oregon cause disinvestments. "Engineered" procedures resulting in high seedling survival characterize public land reforestation at this time. Application of information presented here will avoid disinvestments while ensuring continued forest productivity.

A new sensitivity analysis technique for evaluating trade-offs in time and dollars when comparing natural and artificial regimes is described. Yields and genetics concepts dismiss some of the myths about time lags and incompatibilities of shelterwood systems. Other discussions include pest management, seed, advantages, disadvantages, and considerations for success. Intangible factors influencing natural reforestation accomplishments are featured in case studies.

Shelterwood systems have been in and out of favor for centuries. Their flexibility allows adaptation to changing landowner desires. Shelterwoods can balance a forest reproduction equation currently dominated by an artificial approach. Foresters are reminded of the tendency to overdo any system which meets management objectives.

Natural regeneration information is plentiful. The bibliography contains more than three hundred references at this writing. (Specific information can be extracted electronically by keyword sorting.) Accompanying text presents findings from historical records, research publications, associations with colleagues, and the author's experiences. Shelterwood systems were found to be flexible, economical, and productive. Silviculturists are ehallenged to adapt classical methods to today's rapidly changing management environment.

PURPOSE AND INTRODUCTION

This paper provides forest managers with a descriptive framework of shelterwood systems and their application potential. The social environment for such applications is characterized by continuously-reduced personnel and investment capital, coupled with continuously-increased demands for both commodities and amenities. Rather than being prescriptive, the paper assists in development of management direction via investigation of literature pertaining to shelterwood systems. The paper begins to answer a question so important to today's forest executive: "What is really known about natural regeneration?"

Conceptual frameworks are developed for evaluating shelterwood method consequences relative to yields, economics, genetics, seeds, and pests. The selected annotated bibliography contains references to natural regeneration and shelterwood systems in the Pacific Northwest. Ideas presented here can balance a forest reproduction equation currently dominated by an engineered, expensive approach. Decision makers who are coping with reduced budgets and personnel will find that shelterwood systems are practical, historically well-founded, and likely to enjoy expanded future applications.

BACKGROUND

Recent reforestation history in south-central Oregon can be characterized as a period of rapid technological advancement in both public and private sectors. The attention focused upon predictable reforestation success by foresters and the general public in recent years is remarkable when considered within the larger framework of Pacific Northwest conservation history. Only since the mid-1970's have consistently acceptable reforestation results been realized throughout most of the interior Northwest. Technological progress came about through intensive application of skills and knowledge and substantially increased investment levels. Additionally, commitment to success by the administrators of public and private land resource agencies and businesses reinforced the Northwest reforestation technology revolution.

During this period, employee training and development also intensified. For example, in the public sector, the USDA Forest Service's Area IV (Pacific Northwest Region)--an aggregation of the Ochoco, Deschutes, Fremont, and Winema National Forests--created an unique position: Area Reforestation Specialist. That position was first filled by the late Michael B. Panelli. Panelli's efforts in technology transfer of highly successful planting techniques were instrumental in leading the Area away from less than fifty percent first year survival rates to predictable rates above ninety percent. Such success has been consistent for the past seven years on each of the fifteen Area IV ranger districts. Prior to this time, only a few

Area IV districts experienced high survival rates. Credit is also due to nurseries which responded to the challenges of the forest industry boom year's of the 1970's by developing more viable seedlings. Credit is due to every person involved with forest regeneration on the typically hot, dry, relatively lower productivity sites of south-central Oregon during the 1970's. These have truly been times of pioneer forestry effort.

As reforestation rapidly evolved from "rehabilitation" and became "big business", typical Area IV national forest ranger districts managed quarter of a million dollar yearly budgets in reforestation. Some very carefully engineered systems were developed--systems which removed most of the risks and accompanying uncertainties of the past: 1. absolute control of the site by thoroughly removing competing vegetation, 2. intensively-cultured seedlings possessing high survivability, 3. careful handling and planting of those seedlings, and 4. extraordinary animal damage protection such as fences and protective cages. These artificial systems and devices resulted in success where failure had gone before.

Area IV forestry practices, as is true of American forestry practices, generally, are founded upon a European forestry heritage. In examining European forest management history, one finds that patterns of conflict and shifts in direction are not new. Often, previously scrapped strategies have been recycled. <u>Tire et aire</u>, a fifteenth century French precursor to the shelterwood systems that we implement today, was partly developed in response to abusive practices of "selective" cutting that characterized the darker sides of European

forest history (Troup 1928). By the mid-eighteenth century in Germany, clearcutting with planting or artificial seeding became popular (Smith, 1972). Such practices fell into disrepute during the latter part of the last century. Smith further clarifies, "This was not a shift away from clearcutting and planting..., but the development of widely diverse silvicultural approaches carefully fitted to the circumstances."

Later, railroad logging in the United States, particularly in the West, was associated with numerous abuses of clearcutting and so-called "selective" cutting. In Area IV, frustration about uncertainties associated with forest reproduction accompanied partial-cutting practices until the mid-1970's.

In the current period, the Area IV situation can be characterized as one in which full site control is achieved, most often via clearcutting, followed by mechanical or fire methods of further vegetation removal and site preparation. Then, the most vigorous seedlings are produced from seeds collected from the most desirable sources available for a given area. Next, through sometimes extraordinary storage and handling practices that involve sophisticated refrigeration units, stress-reducing handling practices, and a planting contract that is as procedurally foolproof as can be, most stands are reproduced with high degrees of certainty. The standard procedures developed in Area IV represent a high level of technological intensity.

Major shifts in national forest policy have been stimulated by political pressure. The Bitterroot controversy of the 1960's

influenced a trend away from clearcutting and toward partial cutting in the interior West. Later, the National Forest Management Act of 1976, spawned by the Monongahela Decision, conferred legitimacy to _all_ silvicultural systems. Shelterwood methods were applied widely throughout Area IV during the 1960's and 1970's. Not only did shelterwoods provide ways of dealing with the uncertainties of reforestation, sometimes their use was simply politically expedient.

The method, as typically applied, involved a two step approach. First, a seed cut often left cull, mature, lower-value species at some regular spacing, say fifty feet. Then following piling and burning of the slash, ponderosa pine (_Pinus ponderosa_) seedlings were planted. Sometimes, residual trees were damaged or destroyed during slash treatment operations. Removal cuts were not often prescribed _per se_, as one predecessor said, "to leave options for the future". At the time of most of the seed cuts, it was doubtful if removal cuts could be carried off without destroying the reproduction, or because of low values of the seed tree stumpage. Often, shelterwood systems were employed as ways of softening otherwise harsh appearances of freshly-logged units. Frequently, grasses were seeded to disturbed areas after site preparation and before planting. By the late 1970's, "political shelterwoods" had become disdainful reminders of past failures.

Political pressure continues to demand response. Today, the federal budget deficit looms as a most important threat in government. Analogously, in the wood products industry, anything that contributes to reduction in positive cash flow is a problem to be

solved. It takes at least $400 per acre to create typical Area IV national forest plantations, often much more, seldom less. Private sector investments are about half of those levels. Stumpage at $100 or less per thousand board feet on lands that yield fifty cubic feet per acre per year does not provide a setting for desirable investments. In the 1980's, land managers are looking for new "old" ways to cope with uncertain economic environments characterized by depleted investment capital and personnel reductions. It is appropriate, then, to turn to the classics of the forestry profession for insight into the broad array of practices that might be re-applied or developed further in light of today's knowledge of forest ecology and plant physiology.

THE MANAGEMENT ENVIRONMENT

Several factors influence the management climates of both national forest administration and the forest products industry. Principally, the quest for cost reduction is shared by both segments of society. Additional factors are the results of research, reports, and investigations developed within regional and forest offices--particularly during the current forest planning process as stipulated by the National Forest Management Act. The Oregon Forest Practices Act requires rapid reforestation which tends to lead private sector forest managers into artificial regeneration measures. However, the Northwest forest industry has changed its management direction in recent years. As one colleague in the private sector recently remarked, "Sure, I can still do all the (mechanical) site prep I need to do...for thirty-five bucks an acre!" In the USDA Forest Service, the same message comes through in the form, "Expect a ten percent reduction in personnel next fiscal year". In this report, the national forest administration environment, particularly as it affects the national forests of south-central Oregon, is considered.

First, the need to reduce the cost of government programs has been recognized by federal managers for some time, especially during the last four years. Most federal administrators acknowledge that although the current cost reduction thrust is associated with "Reaganomics", it is nevertheless a force which crosses political bounds and for which "the time had come". Since reduction of the federal deficit is one of the highest national priorities,

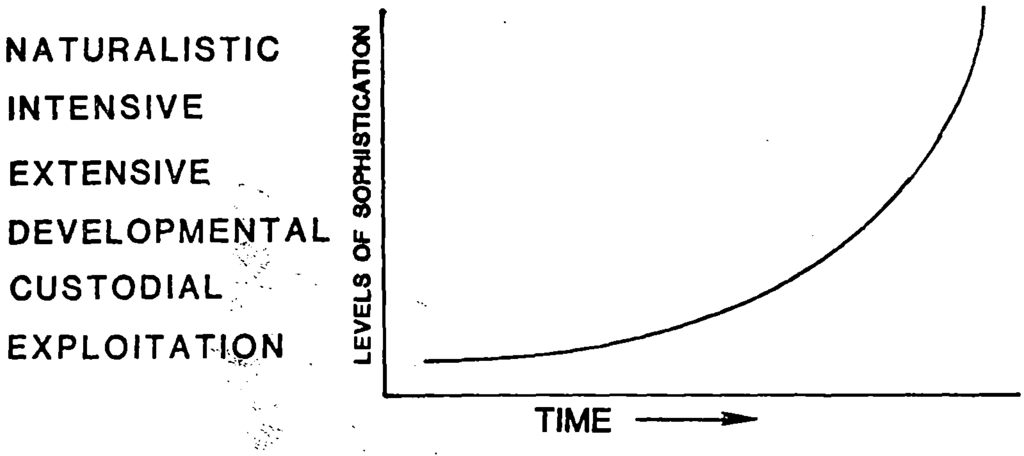
opportunities for cost reduction and contributions toward positive cash flow into the national treasury have become dominant driving forces. At the same time, because of an ingrained organizational ethic providing "for the greatest good for the greatest number in the long run", continued adherence to the highest standards of multiple-use land resource management is likely to remain. The seeming paradox of reducing costs while keeping quality standards high is but another expression of the management climate in which most managers find themselves today. Creative management of apparent dichotomies has become a hallmark of the successful 1980's executive (Naisbitt 1982, Peters and Waterman 1984).

In 1983, the Chief of the USDA Forest Service issued a report titled "A Productivity Improvement Analysis: Reforestation" (USDA Forest Service 1983). Four issues were investigated: natural regeneration techniques, reforestation success, reforestation of low productivity sites, and (so-called) non-project reforestation costs. The recommendation derived from inquiry into natural regeneration is: "Where permitted by the management guidelines and objectives of the individual forest plans, require the consideration of natural regeneration as an alternative in regeneration prescriptions, but select the best overall method from the evaluation of economic, silvicultural, and other resource criteria." Further, Forest Service Manual 2472.5, Region 6 Supplement No. 322, was added in March, 1984 to accomodate the new emphasis (USDA Forest Service Manual 2470). The supplement calls for analysis of all methods for obtaining stocking. Further, the five-year regeneration period referred to in the National

Forest Management Act is clarified as "normally" beginning at the time of overwood removal. Also, direction to consider a natural regeneration alternative is highlighted. Finally, specification of a four percent interest rate and charging of reforestation against the current crop is directed.

At the national forest level in Area IV, both the Deschutes and Winema National Forest Mission Statements have embraced natural regeneration as the primary method of lodgepole pine (Pinus contorta) reproduction. Adjacent to Area IV, the Malheur National Forest goes so far as to specify shelterwood cutting as "the standard regeneration system" (USDA Forest Service 1982). As national forest plans are being developed, natural regeneration systems are receiving considerable emphasis and inquiry. National Forest and Regional Silviculturists from the Pacific Northwest addressed natural regeneration as an important business item at their last two year's annual meetings. Silviculturists at forest and district levels are producing reports and position papers on natural regeneration with increased frequency (Ellen 1983, Petersen and Mohr 1984, Simonski 1984).

Renewed interest in natural regeneration marks the beginning of an era of greater forestry sophistication.



FOREST MANAGEMENT PROGRAM MATURITY

(Adapted from Spurr 1979)

FIGURE 1

If one accepts the above representation, then the quest for economic efficiency is accelerating forest management further toward the naturalistic realm.

Managers are searching for least-cost alternatives as places from which to develop decision frameworks. Further, silviculturists are often led into systems which provide more gradual transitions from one generation to another in order to mitigate perceived landscape harshness resulting from regeneration treatments. A complete understanding of natural regeneration is fundamental to intelligent management direction.

Most field silviculturists are more experienced with plantation establishment methods. Successful natural regeneration results in Area IV are typically by default or natural phenomena. "Get Survival! Get Growth!"--these were resounding forceful directions of the recent past. Dollars were not an issue with Knutson-Vandenburg funds and congressional appropriations for reforestation were virtually without limit. Silviculturists responded by developing some very precise systems for achieving the objectives embodied in those directives.

As federal forest managers simultaneously cope with ever-more severe personnel and budget limitations, while carrying out a multiple-use mission, practices characterized as "natural" silvicultural systems become increasingly appealing. The apparently dichotomous trend toward managing increasing commodity and amenity values, by all indications, will continue (March and Olsen 1979). Natural reforestation is wholly compatible with improved production efficiencies in both commodities and amenities. Shelterwood management promises to reconcile the ambiguity of agency missions with practices that promote harmony between both kinds of values.

There are many barriers preventing expansion of natural regeneration systems applications. An orientation toward plantation forestry which prevents USDA Forest Service managers from taking full credit for regeneration by natural methods is one. Naturally regenerated stands do not answer to regional standards and guidelines (Jaszkowski, personal communication). Adjustment of agency forms and procedures to accomodate natural regeneration would go a long way

toward promoting it. Essentially there is a "plantation mentality", partly a reaction to fear of failure, partial cuttings that high-graded forest stands, and "political shelterwoods". Edgren (personal communication) has cautioned that foresters should not be too afraid to fail, lest progress cease. Further, he attests, "Regionally and historically, we have failed to successfully reforest about one-third of the time." With these perceptions, risk management takes on added significance in the pursuit of cost reduction.

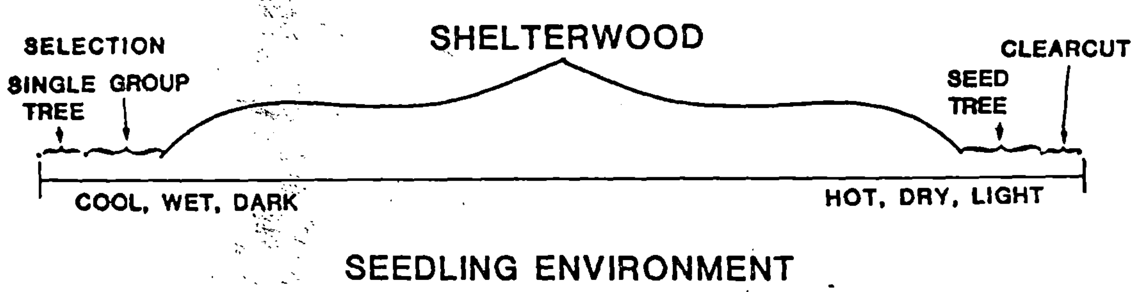
Some may view the current quest for cost reduction as a capricious shifting of direction. Re-examination of history reveals that within the context of political pressure, common sense caused management direction to turn appropriately. It should be remembered that present "heavy-handed", or "high-tech", or "engineering" approaches to forest regeneration were born from years of frustration with the performance of partial-cutting regimes. Some of the past failures led to large-scale, expensive rehabilitation projects.

THESIS

In light of the forgoing brief history and characterization of today's management climate, it is appropriate to investigate classical forestry literature to seek insight into the spectrum of options available. If one looks into land management history, one finds that virtually all "modern forestry methods" are founded upon classical practices that have been applied in European forests for centuries. For example, "unit area control" is a variation of group selection systems that have periodically been in and out of favor with land administrators since the Middle Ages (Troup 1952, Smith 1972). Intensive management can take on varied dimensions. Faced with personnel cutbacks and declining budgets in the "information age", a manager may find it prudent to invest greater proportions of scarce financial and personnel resources in technology acquisition and transfer. This idea leads to a less familiar form of intensive management: intensity of thought, research, and cleverness of application (Lee, personal communication; Scott, personal communication).

There is a considerable body of information and experience that may be used to reduce the costs of quality reforestation while concurrently addressing the concerns and desires of the American people. Future demands on professional foresters may not include rigid applications of well-engineered methods. Rather, creative application of appropriate classical methods may be demanded.

Only shelterwood systems embrace all of the advantages outlined in the Advantages and Disadvantages section of this paper. Further, although other methods may acceptably regenerate some northwestern tree species, shelterwood methods can create ideal seedling environments for all species. While there are few forest regeneration situations that require shelterwood methods, there are even fewer that require other methods.



(adapted from Scott, personal communication)

FIGURE 2

The environmental amplitude of various silvicultural systems is illustrated above.

Success can be measured not only by how many acres were planted each year, but by how clever foresters have been in achieving land management objectives with limited capital and personnel. As further insights are gained into forest stand dynamics, they can be blended with knowledge from classical silviculture in order to more accurately predict outcomes relative to the type, timing, intensity, and extent of ecosystem disturbances.

Many of today's foresters have only limited experience with natural regeneration systems. However, experience gained through

successful plantation establishment by creating favorable seedling environments is readily transferable to natural regeneration technology (Cleary, personal communication). Artificial reforestation methods also provide backup systems that can be employed when natural regeneration systems fail to produce desired results.

All variables considered, shelterwoods offer the most flexible systems. Shelterwoods also provide opportunities for effectively reducing high, up-front investment costs while mitigating most of the ill effects of standard current practices (White and Graham 1978). Shelterwood systems have wider applicability, particularly in Area IV, than current practice demonstrates (Hopkins, personal communication). Given public attention to cost reduction and opportunities to increase revenues in government, shelterwood systems deserve increased attention. In light of accelerated evolution toward naturalistic systems, this can be seen as a further degree of intensification, not a back-slide to old ways of failure.

A framework for the future has been drawn. That framework is founded upon knowledge extending back to the Middle Ages. This paper compiles and summarizes much of the information that can be useful to foresters working to reduce reforestation investment costs on low to medium-site-quality lands. A balanced perspective can be achieved when considering alternatives available to reproduce forest stands. The appendix: SELECTED ANNOTATED BIBLIOGRAPHY OF NATURAL REGENERATION AND SHELTERWOOD SYSTEMS LITERATURE (electronic), is available through the Forest Level Information Processing System of the Winema National Forest, Klamath Falls, Oregon, and the WESTFORNET Library (University

of Washington). It may be updated, appended, or edited at the user's discretion.

Although much of this paper's emphasis is directed toward south-central Oregon national forest lands, most of the concepts explored and described apply to other forest types and ownerships as well.

LIMITATIONS AND SCOPE OF THE STUDY

Thorough investigation of classical forestry would require a scholar's lifetime. Further, the study is limited primarily to English language publications because it is concentrated on interior Northwest silvicultural practices. The University of Washington library (center for this investigation) contains one of the world's most complete forestry collections. Library research here has allowed expansion beyond what would have been possible otherwise. Concurrent tutorial study with Dr. David R. M. Scott extended depth and quality of the research.

This was a study of technical literature as well as recorded experiences of the author and his colleagues. The main research publications reviewed were from the "applied" research community. More "whys" would likely have been answered through intensive investigation into the "original" research base. Although the study is focused on shelterwood systems, it draws attention to a larger body of natural regeneration knowledge. The focus, itself, is limiting.

Cause-effect conclusions await results of long-term monitoring.

GLOSSARY OF SELECTED TERMS

advance(d) regeneration
    Nature made the seed cut; space became available naturally (Scott, personal communication).

competition
    predation (q.v.), a negative effect: density-induced impoverishment of the environment (Scott, personal communication) (see mutualism)

density adjustment
    regulation of stocking

even-aged
    (referring to stands or management) one or two distinct age groups

forestry
    "what we do in the woods", attributed to D. M. Smith (see silviculture).

group shelterwood
    clear-felled area of appropriate size and shape so that most of the regeneration senses the surrounding stand during a (critical) regeneration period (see uniform shelterwood and strip shelterwood).

intensive management
    concept: refers to intensity of thought as well as action (Lee, personal communication; Scott, personal communication)

intolerant
    inability to live beneath a superior-statured interactant (see tolerant)

irregular shelterwood
    complex of uniform, strip, or group methods so that overall appearance is one of irregularity

management direction
    the course of activities one takes in order to arrive at a state which satisfies the desires of management

management environment
    the framework of social, economic, and biological parameters, including goals, in which the forester must work

method
    the procedure used in forest manipulation (see system)

mutualism
    an improved, positive effect; a density-induced improvement of the environment (Scott, personal communication) (see competition)

pest
    organism which diminishes desired resource values

predation
    in addition to common usage, refers to the competitive effect of vegetation which "pre-dates" newer vegetation, as in overstory to understory relationships

preparatory cut
    light felling (one or more) to improve stand condition

removal cut
    fellings (one or more) which remove overstory after regeneration establishment; a final removal cut removes all remaining overwood

seed cut
    a single felling for creating a favorable regeneration environment
seed tree
    a source of reproduction; or, a method or system which leaves a seed source, not shelter, for the new generation
shelterwood
    referring to the seedling environment; aspect, exposure, and "dead shade" may contribute to the effect; method or system wherein the new generation experiences influences of the older generation during some part of its establishment period
silviculture
    "what we do to the woods", attributed to D. M. Smith (see forestry) or, manipulation of forests in order to meet land management objectives
    Daniel (personal communication): "Silviculture is getting what you want, with the least effort, for the greatest return. You have all the tools except time."
site preparation
    manipulation of the <u>non-living</u> part of the environment
strip shelterwood
    clear-felled strip of such dimension that most of the regeneration is influenced by the surrounding stand during a (critical) regeneration period (see uniform shelterwood)
system
    named by the method (q.v.) used in forest renewal; system includes the activities of an entire rotation
tolerant
    ability to live beneath a superior-statured interactant (see intolerant)
uniform shelterwood
    characterized by relatively uniform distribution of seed trees in a manner analogous to heavy thinning (see group shelterwood and strip shelterwood)
wedge shelterwood (Troup 1928, 1952, Spurr 1956, Jaszkowski 1975)
    wedge-shaped unit pointing into prevailing winds; provides wide variety of seedling environments
weed
    n. undesirable vegetation; v. remove undesirable vegetation
yield
    more than dry weight biomass; could refer to yields of water, visual resource quality, etc.

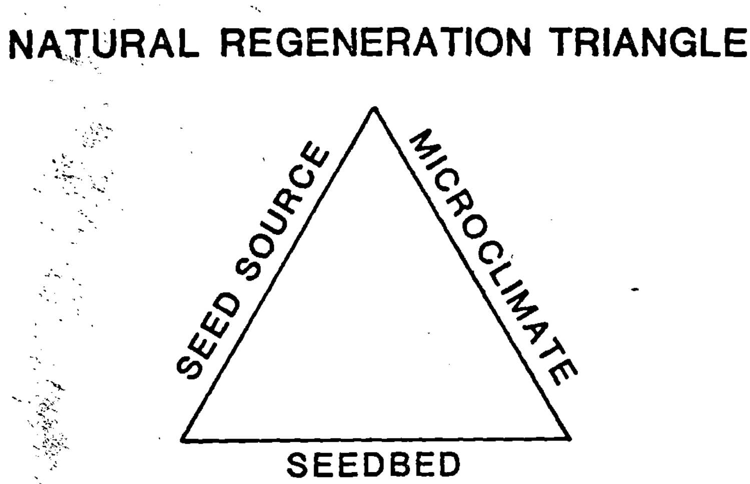
LITERATURE REVIEW AND FINDINGS

Literature review was conducted at the University Of Washington and WESTFORNET Forestry Libraries in January, February, and March, 1985. The following computer data bases were searched: AGRICOLA (U.S. National Agricultural Library), CAB (Commonwealth Agricultural Bureaux), BIOSIS (Bio-Sciences Information Services), FEDERAL RESEARCH IN PROGRESS, and NTIS (National Technical Information Service). Review of all volumes of Forestry Abstracts provided further initial leads. Manual cross-referencing characterized the investigation after pertinent publications were drawn from the overview.

After overview of all available natural regeneration literature, investigation focused on study results (particularly shelterwood research) most relevant to south-central Oregon. USDA Forest Service Experiment Station reports formed the shelterwood and natural regeneration information core. Additionally, staff from the USDA Pacific Northwest Forest and Range Experiment Station, Pacific Northwest Region Silviculturists, collegues in the Northwest forest industry, and faculty at the University of Washington and Oregon State University were consulted frequently during and after the review. The author's experiences and contacts with associates over his past eleven years' forestry practice in the Pacific Northwest are also incorporated in the text.

Regeneration Triads

Many foresters characterize a forest reproduction spectrum as encompassing three concepts. Daniel, Helms, and Baker (1979) as well as Franklin and DeBell (1973) refer to the regeneration triangle of Roe, Alexander, and Andrews (1970). Daniel (personal communication) has referred to this triad as the "Eternal Triangle". A regeneration triangle for natural reproduction is illustrated below.



(adapted from Roe, Alexander, and Andrews, 1970)

FIGURE 3

The "BAR" Plan for reforestation (adapted from Scott, personal communication), in its broadest context, means:

manipulation of the Biotic part of the environment

manipulation of the Abiotic part of the environment

provision of the Reproductive source

Within the silviculturist's purveyance, this further means:

1. making space available for the next generation (vegetation

manipulation).

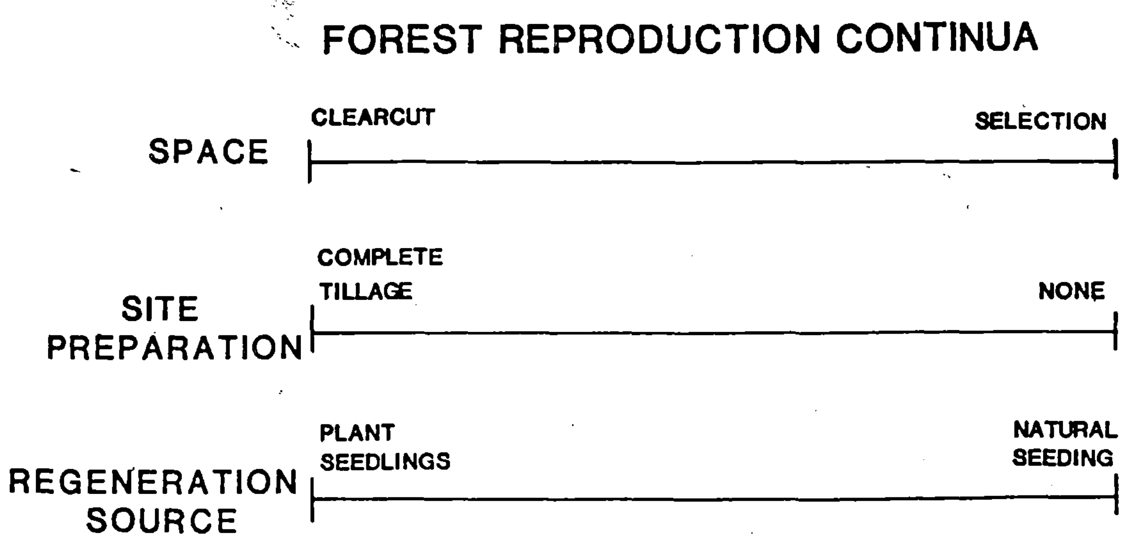
2. massaging the non-living part of the environment.

3. providing a source of the new generation.

A fourth dominant element, beyond ecologic setting, involves the objectives and desires of forest land owners. Choices of silvicultural methods are rarely dependent upon ecological factors. Such choices often depend upon management direction (Franklin and Debell 1973).

The Shelterwood Method

In the shelterwood method, the new generation perceives influences of the older generation during some (usually critical) point in its life. In contrast to other high-forest even-aged reproduction methods, the seed tree method denotes a source of seed, whereas the clearcut method provides for no living interaction (Scott, personal communication).



(adapted from Scott, personal communication)

FIGURE 4

Note how each continuum can be caused to interact in many variable ways. Also note that the first two parts of this triad are concerned with the (favorable) seedling environment (Cleary and Greaves 1974).

Through gradual removal of the older generation, a new stand is established. Preparatory cuts provide for development of the better trees which exhibit windfirmness and seed production potential. Then, the seed cut removes a portion of the dominant vegetation, providing space for the new generation. Finally, removal cuts take away the older generation during and after establishment of the new generation. In its simplest form, the shelterwood method is only a seed cut followed by a removal cut. The shelterwood method is infinitely variable, with uniform, irregular, group, strip, and wedge (Troup 1928, 1952; Spurr 1956, Jaszkowski 1975) types being commonly employed with varying timings, intensities, and extents.

Because of the wide ecological amplitude of seedling environments that can be created by various shelterwood systems, it is wise to consider shelterwood application wherever imitation of natural processes is desired (Smith 1970). Studied observation of regeneration responses to treatments and natural disturbances can reveal where the minimum and optimum requirements for seedling survival and growth are. Daniel, Helms, and Baker (1979) review Mitscherlich's "law of the minimum" and Mayr's "zone of the optimum". Franklin and Debell (1973) concluded that regeneration success is determined by the environmental elements of temperature, moisture, and light.

ENVIRONMENTAL GRADIENTS

(adapted from Smith 1962, Franklin and Debell 1973, Hermann 1978)

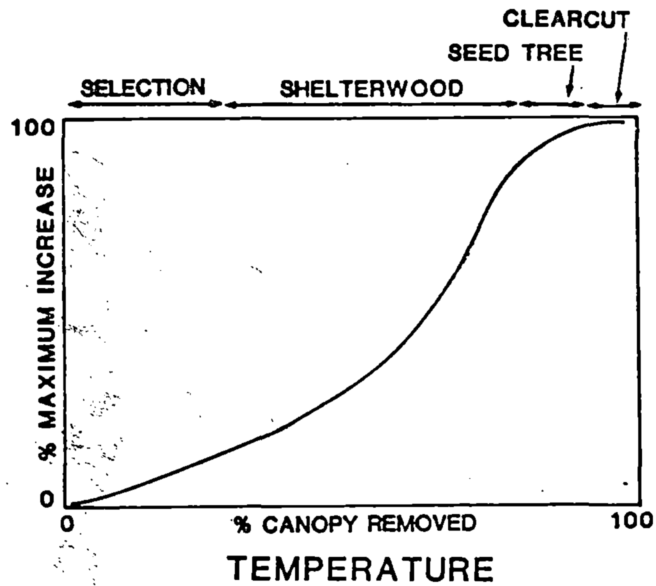


FIGURE 5a

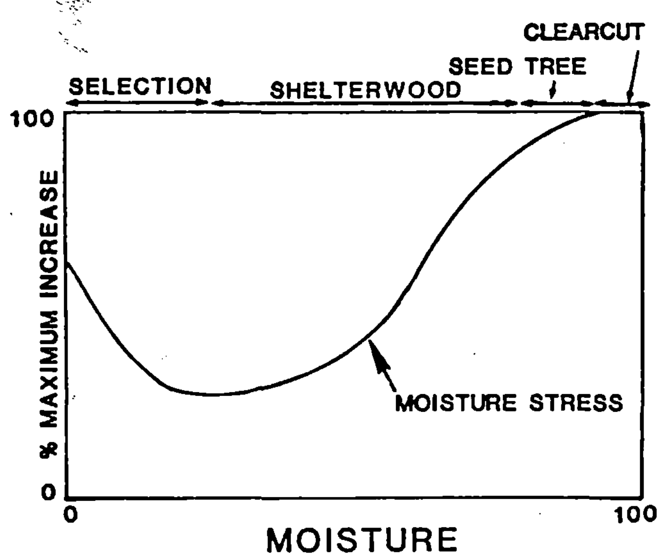


FIGURE 5b

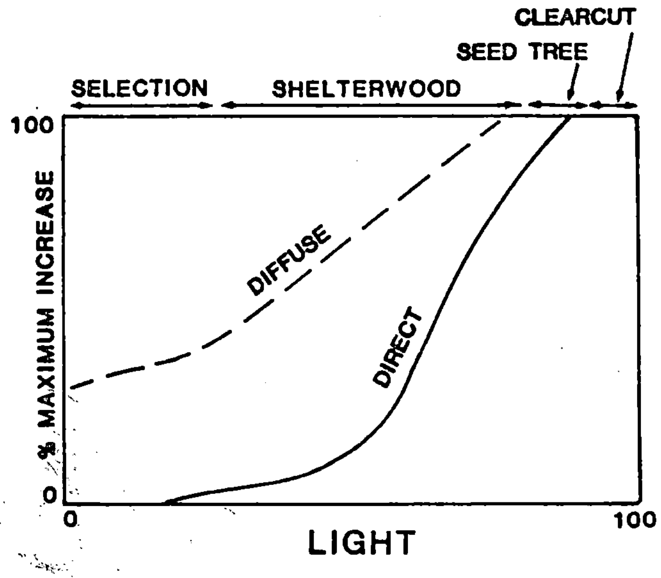

CLEARCUT
SEED TREE
SELECTION
SHELTERWOOD
100
% MAXIMUM INCREASE
DIFFUSE
DIRECT
0
0
100
LIGHT

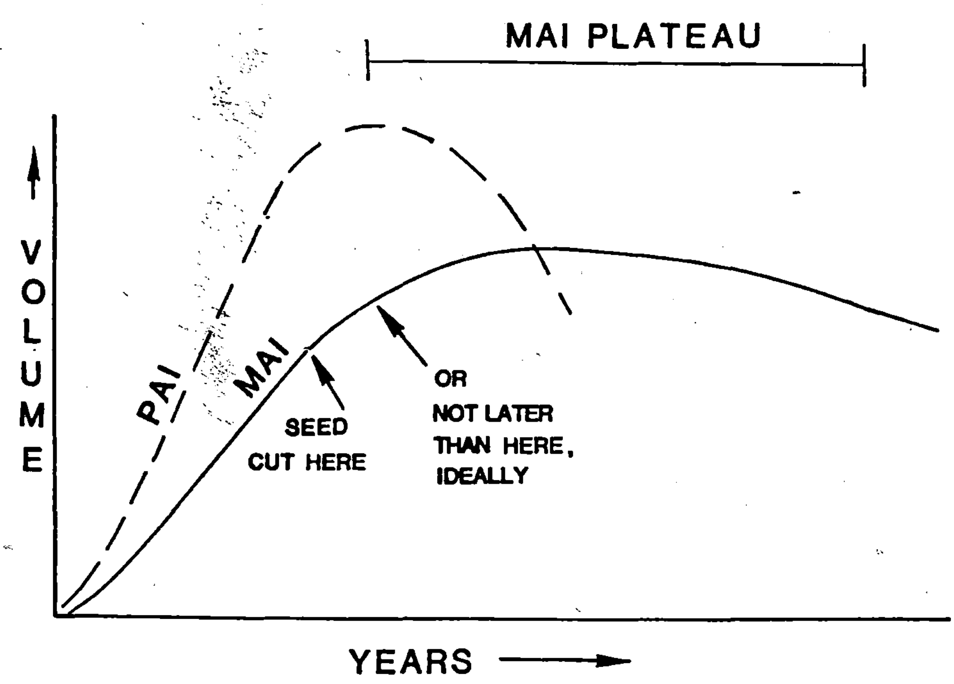
FIGURE 5c

Yields

Regeneration lag time and attendant fall-down in wood fiber yield are major concerns about natural reproduction systems. During the seed cut phase of a shelterwood application, growing space is ideally occupied by neither the older nor newer generation. Some space is sacrificed for the continued existence of the mature generation (Scott, personal communication). Further, foresters using natural regeneration techniques are often faced with the extremes of two disparate occurrences--understocking or overstocking. Often, distribution of stocking is clumpy, exhibiting the consequences of overstocking and understocking on the same site. With understocking, one is required to wait longer and suffer reduction of potential yield. With over-stocking, one is required to adjust density early and add to up-front costs.

In natural group shelterwood systems (with advance reproduction), how can growth loss from physiological suppression be assessed? Scott (personal communication) has suggested that measurement techniques are not sophisticated enough to answer this question. Not only do board foot volume measures fail to give true productivity quotients, but most yield expressions typically overlook total biomass production.

Drawing upon Mar-Moller Curves, Langsaeter's Curves and stand growth projections from models such as PROGNOSIS and LPSIM, shelterwood system yield concepts are developed (Smith 1962; Williamson 1966; Erteld 1970; Stage 1973; Daniel, Helms, and Baker 1979; Dahms 1983; Scott, personal communication):



VOLUME-TIME RELATIONSHIPS

FIGURE 6

A series of shelterwood regimes:

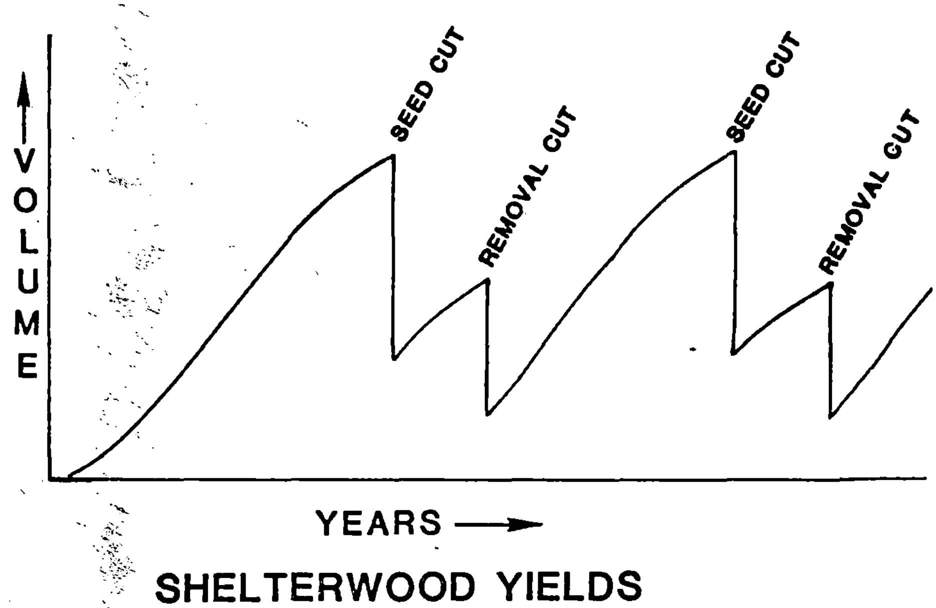
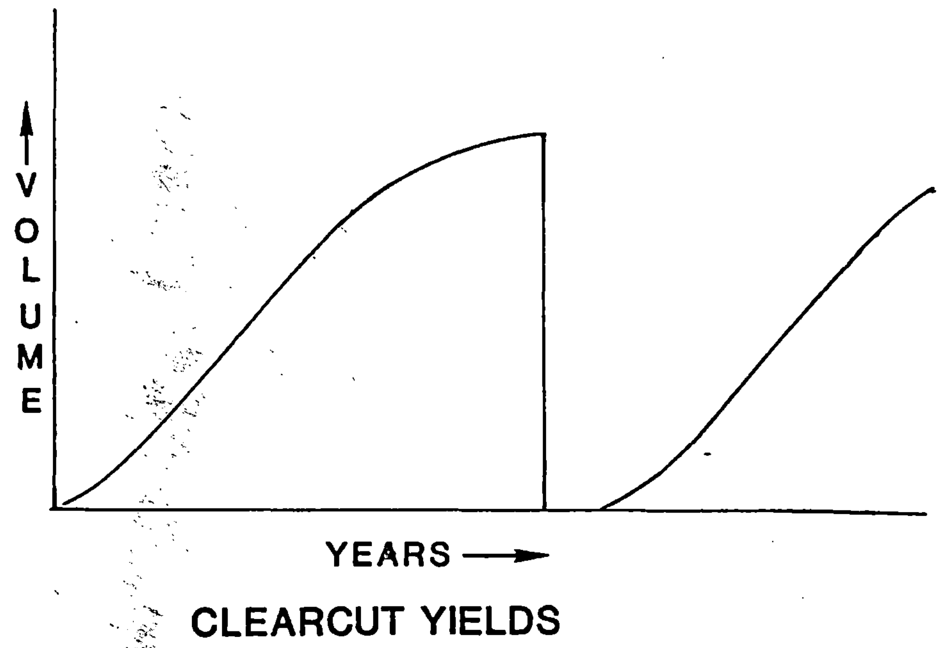


FIGURE 7

A series of clearcut regimes:

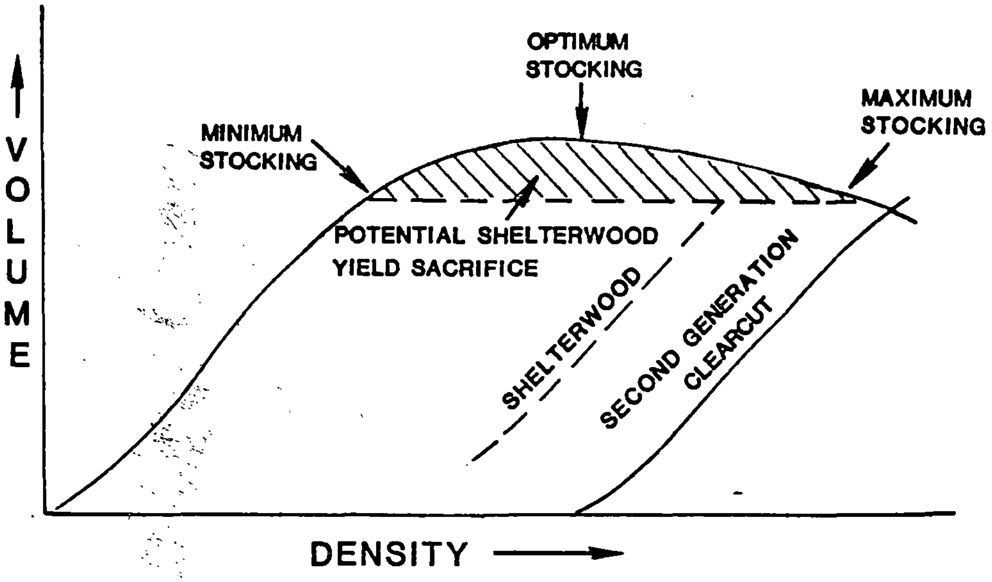


(Note time lag before site occupancy is achieved.)

FIGURE 8

By beginning the shelterwood system (preparatory cuts and seed cuts) somewhat sooner than at the precise point of culmination of mean annual increment (where PAI = MAI), there is a theoretical trade-off when compared to a clearcut and plant scenario. Measured against the time delay required to achieve full site occupancy of a clearcut and plant regime, is the difference real and measureable? The answer is academic.

The seed cut uses space and time efficiently during the "MAI Plateau" period in obtaining a new stand while continuing to grow the best of the old:



VOLUME-SPACE RELATIONSHIPS

Yield is reduced for a given rotation, but a new generation is started sooner.

FIGURE 9

Allowing sufficient time to work within the "MAI Plateau" and overlapping or "telescoping" (Smith 1979) the generations, results in little measureable yield impact. Key factors are seed cut timing during the "MAI Plateau" period, vegetation control, and durable site preparation. Additionally, direct seeding and planting provide backup alternatives. Current widely-applied procedures of clearcut, site preparation, and planting ensure ultimate backup capabilities.

Economics

A principal attraction of natural reforestation is relatively lower cost in the early part of a rotation. The current management environment makes that fact particularly relevant as stumpage values have declined markedly while planting costs have soared. Changes in either planting costs or stumpage outlooks for the future could dramatically affect degrees of risk that forest managers would be willing to bear when implementing natural regeneration systems. The following examples illustrate a procedure for evaluating trade-offs in time and dollars when comparing planting with natural reproduction.

INTRODUCTION

Modern software enables economic sensitivity analyses in convenient and rapid ways. Economics packages associated with stand projection models such as PROGNOSIS (Stage 1973), as well as local programs used in development of yield and economic worth exhibits, permit foresters to quickly investigate wide ranges of possible outcomes. In the following example, REGIME software (Stanger 1981)--Hewlett-Packard 41 economics program--is used to test the economic worth of five investment designs. After calculating soil expectation values for plantation and natural reforestation investments, a time is specified for the planting regime to begin (immediately, in the example). Then, an equation between planting and natural regimes is set up (Hunt, personal communication). Solving for n (number of years to achieve natural reproduction), a seed crop

waiting period can be determined. Independent variables are costs to prepare sites for planting or natural seeding, planting costs, density adjustment costs, stumpage values, timing of activities, and interest rates.

Two alternatives prescribe planting; three others plan for natural regeneration. Then the question is raised: How long can one wait, knowing the soil expectation value for a plantation investment, to begin a natural regeneration plan and still approximate the plantation soil expectation value?

By adapting this procedure, silviculturists can develop local sensitivity curves for their stands. Then, reasonable waiting periods for seed crops may be determined.

ASSUMPTIONS

Many factors influence the economic efficiencies of plantation or natural regeneration systems. These cash flows could be expected on moderate east-side mixed conifer sites. Bias toward planting, in the foregoing examples, has been expressed by 10% greater returns, cheaper density adjustments, and shorter rotations. Discount rate is four percent (USDA Forest Service 1983). Displays have been simplified so that logic of the procedure may be most apparent.

Comparative illustrations of cash flows and soil expectation values for planted and natural regeneration regimes follow:

CASH FLOW TABLES

	PNW_{P1}		PNW_{P2}		PNW_{N1}		PNW_{N2}		PNW_{N3}	
	YEAR	NET CASH FLOW ($)	YEAR	NET CASH FLOW ($)	YEAR	NET CASH FLOW ($)	YEAR	NET CASH FLOW ($)	YEAR	NET CASH FLOW ($)
REGENERATION	1	-400.00	1	-300.00	1	-200.00	1	-150.00	1	-100.00
PRECOMMERCIAL THIN	10	-75.00	10	-75.00	15	-100.00	15	-100.00	15	-100.00
COMMERCIAL THIN	40	1,540.00	40	1,540.00	50	1,400.00	50	1,400.00	50	1,400.00
REGENERATION HARVEST	80	3,300.00	80	3,300.00	90	3,000.00	90	3,000.00	90	3,000.00
DISCOUNT RATE		1.04		1.04		1.04		1.04		1.04
CALCULATED OUTCOMES										
INTERNAL RATE OF RETURN		4.08		4.41		4.16		4.41		4.73
PRESENT NET WORTH ($)		28.65		124.80		37.09		85.17		133.24
BENEFIT/COST RATIO		1.07		1.37		1.15		1.43		1.88
FUTURE NET WORTH ($)		660.39		2876.72		1265.49		2905.85		4546.20

LEGEND

PNW_P = Present Net Worth of Planting Regime
PNW_N = Present Net Worth of Natural Regime

TABLE 1

EQUATIONS FOR DERIVING SOIL EXPECTATION VALUES (SEV)

$$SEV_P = PNW_P + \frac{PNW_P}{(1.04)^{80}-1}$$

$$SEV_N = PNW_N + \frac{PNW_N}{(1.04)^{90}-1}$$

TABLE 2

CALCULATED SOIL EXPECTATION VALUES

SEV_{P1} = \$ 29.95

SEV_{P2} = \$130.46

SEV_{N1} = \$ 38.21

SEV_{N2} = \$ 87.21

SEV_{N3} = \$137.26

TABLE 3

EQUATIONAL RELATIONSHIPS BETWEEN PLANTATION AND NATURAL REGENERATION INVESTMENTS

$$\frac{SEV_P}{(1.04)^o} = \frac{SEV_N}{(1.04)^n}$$

$$(1.04)^n SEV_P = SEV_N$$

$$(1.04)^n = \frac{SEV_N}{SEV_P}$$

$$n \log 1.04 = \log \frac{SEV_N}{SEV_P}$$

$$n = \frac{\log \frac{SEV_N}{SEV_P}}{\log 1.04}$$

TABLE 4

YEARS TO REALIZE COMPARABLE SOIL EXPECTATION VALUES
(YEARS TO WAIT FOR ADEQUATE SEED CROP)

Plantation Investments at $400 Per Acre Versus
High, Medium, and Low Natural Regeneration Investments

SEV_{P1} vs. SEV_{N1}, n= 6.2 Years (natural seeding favored)
SEV_{P1} vs. SEV_{N2}, n= 27.4 Years (natural seeding favored)
SEV_{P1} vs. SEV_{N3}, n= 38.8 Years (natural seeding favored)

Plantation Investments at $300 Per Acre Versus
High, Medium, and Low Natural Regeneration Investments

SEV_{P2} vs. SEV_{N1}, n=(-)31.1 Years (planting favored)
SEV_{P2} vs. SEV_{N2}, n=(-)10.1 Years (planting favored)
SEV_{P2} vs. SEV_{N3}, n= 1.3 Years (no significant difference)

TABLE 5

Given the projected cash flows, if planting expenses on sites in this example could be reduced to less than three hundred dollars per acre, with fairly high probability of success, then plantation investments would be favored. As planting costs approach four hundred dollars per acre, natural regeneration becomes more favorable.

Carrying the examples further, local sensitivity curves (FIGURE 11) may be developed. The vertical axis represents soil expectation values derived for planting regimes. Curves represent soil expectation values for various intensities of natural regeneration investments. The horizontal axis represents numbers of years that one could reasonably wait to begin natural regeneration regimes.

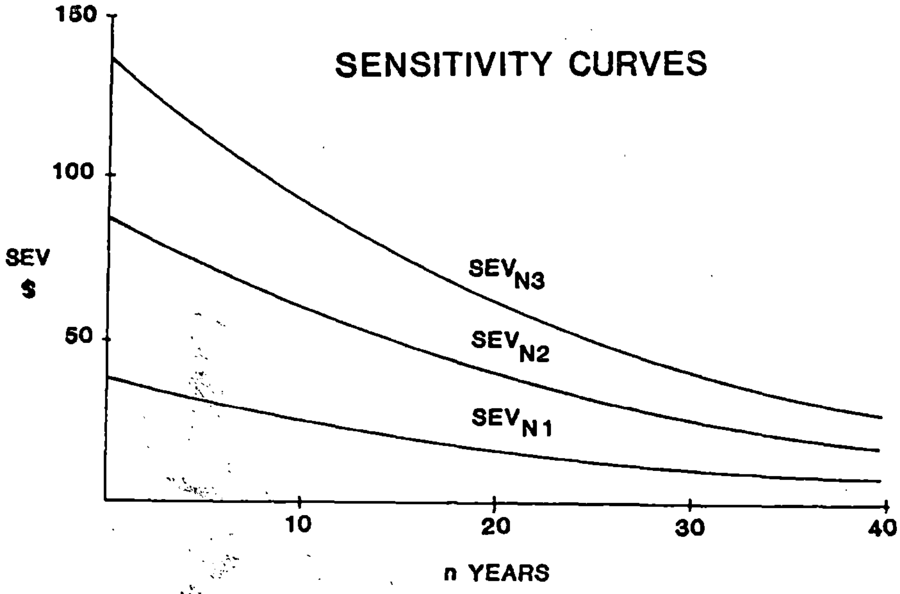


FIGURE 10

DISCUSSION

Additional factors influencing economic worths of shelterwood systems include log qualities at preparatory, seed, and removal cut stages, special logging costs, road construction costs, road maintenance costs, and market volatility during a rotation. Harvest and administration costs increase with increasing sophistication of cutting practices. Postponement of after-harvest investments generally improves present net worth on low to medium site-quality lands.

Vegetation control and site preparation may require repeated application if undesirable vegetation dominates the site or if a seed crop fails. When natural reproduction fails, backup methods cause reforestation expenses for the failed site to be especially high.

Multiplying (subjective) "probability of success factors" by the calculated present net worths could also alter outcomes significantly:

PRESENT NET WORTH			PROBABILITY OF SUCCESS		ALTERED OUTCOMES
PNW_{P1}	\$ 28.65	X	90%	=	\$25.76
PNW_{P2}	\$124.80	X	80%	=	\$99.20
PNW_{N1}	\$ 37.09	X	80%	=	\$29.67
PNW_{N2}	\$ 85.17	X	75%	=	\$63.88
PNW_{N3}	\$133.24	X	67%	=	\$89.27

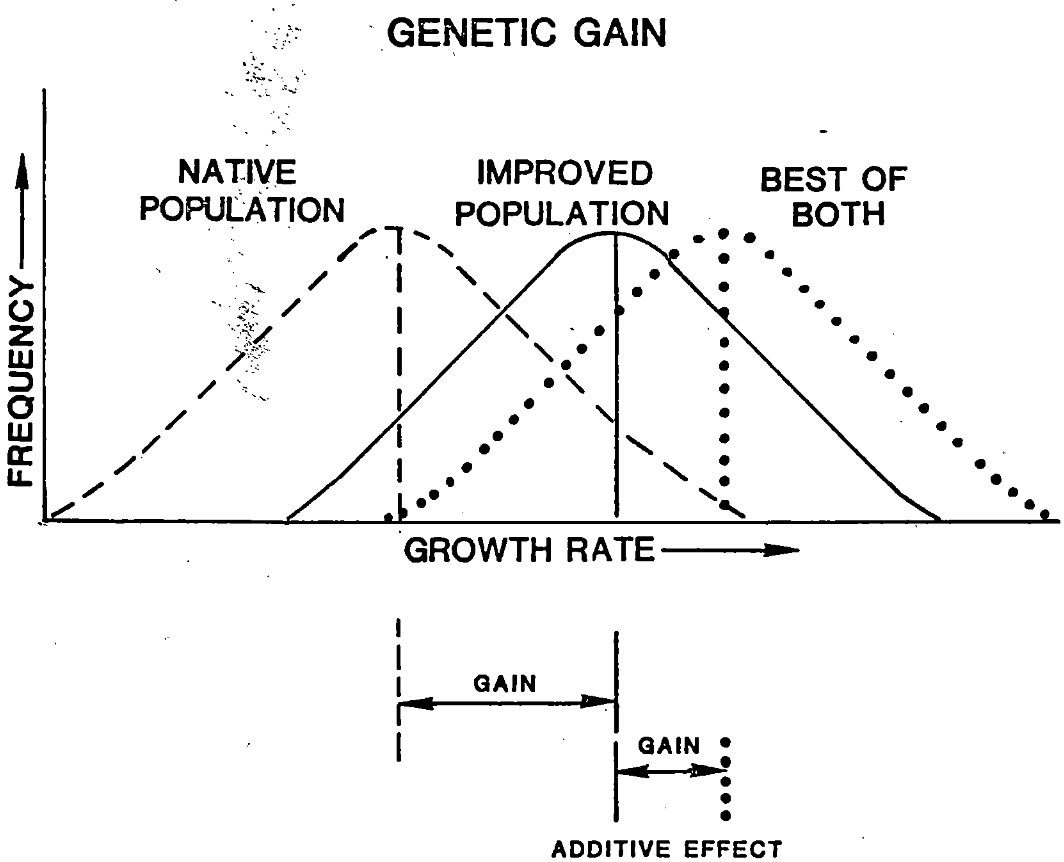
TABLE 6

CONCLUSIONS

These factors favor natural regeneration: (1)increasing interest rates, (2)increasing rotation lengths, (3)increasing plantation establishment costs, (4)decreasing site productivities, and (5)decreasing stumpage values.

Genetics

Natural regeneration systems and forest tree improvement programs are complimentary. In contrast to large-scale artificial reforestation programs, shelterwood systems can allow natural gene pools to remain relatively intact. Mixing natural reproduction, particularly when using even-aged systems (Theisen 1981), with improved planting stock induces additive genetic gain as illustrated below.



(Adapted from Theisen 1978)

FIGURE 11

Substantial genetic gains can occur in shelterwood systems from the effects of seed tree selection upon heritable traits and inbreeding depression (Theisen 1978, 1981). Selection of the number and quality of seed trees exerts the most significant influence on the genetic makeup of progeny. Highly heritable traits such as straightness, forking, or branch size can be appropriately selected for or discriminated against during seed tree reservation (Theisen 1981, Martinson 1985). Quality and intensity of the seed cut determine future stand quality and composition. "What you see is what you get" (Martinson 1985). In most cases, increasing numbers of seed trees are most desirable to a point where the seedling environment begins to become unfavorable. More seed trees represent more (diverse) pollen sources, thus lessening inbreeding potential.

Recent shelterwood studies at the Forestry Intensified Research Program of the Oregon State University Extension Service revealed little loss of genetic diversity and attendant productivity when compared to uncut stands. It was suggested that shelterwoods may be used for maintaining in situ genetic reserves. Continuing shelterwood research in the FIR Program is attempting to confirm indications that seedlings and pollen are comprised of loosely arranged groups of related individuals (Neale and Adams 1984).

Basic knowledge of forest genetics is essential to natural regeneration success. One must be able to recognize stands exhibiting cone crop histories which display adequacy for natural regeneration. Rudimentary understanding of heritabilities is necessary in prescribing seed tree selections. Skillful preparatory cuttings to

regulate spacings and crown exposures of the better trees enhance seed production. Timely fertilizer application can further promote seed crop development. Most important is clever removal of competing vegetation and site preparation timed to coincide with seed fall. When these technologies are combined with the skills and experiences that accompany accurate assessment of seed crop potentials, success is assured (Simonski 1984).

Pest Management

Pest prediction and control require special attention in south-central Oregon reforestation activities. Pest management typically becomes the dominant biological factor in silvicultural prescription formulation. About one third of the costs of reforestation in Area IV, Pacific Northwest Region, USDA Forest Service, can be ascribed to mammalian animal damage management (Horton and Cleary 1984). Success or failure of forest regeneration is directly related to quality of pest management immediately before, during, and after reforestation activities. Primary pests associated with forest reproduction in south-central Oregon are highlighted below.

Pocket gophers (*Thomomys spp.*) have caused the destruction of several Area IV forest plantations. Mountain pine beetle (*Dendroctonus ponderosae*) and western pine beetle (*Dendroctonus brevicomis*) epidemics of recent years have forced the most sweeping changes in Area IV harvest patterns since World War II. Fir engraver (*Scolytus ventralis*) often adversely affects the crowns of many true firs and Douglas-firs. Outbreaks of western spruce budworm (*Choristoneura occidentalis*) and Modoc budworm (*C. viridis*) have prompted several large-scale aerial spray projects. Dwarf mistletoe (*Arceuthobium spp.*) infects nearly all wild stands to varying degrees. Decay associated with armillaria (*Armillaria mellea*) and laminated [*Phellinus* (*Poria*) *weirii*)] root and stem rots, fomes (*Fomes annosus*), Indian paint fungus (*Echinodontium tinctorium*), and losses

associated with white pine blister rust (*Cronartium ribicola*), western gall rust (*Peridermium harknessii*), etc. represent losses greater than those due to wildfire or that could be counterbalanced by improving yields through breeding programs and cultural practices. Dwarf mistletoes (*Arceuthobium spp.*) substantially contribute to those losses, also. Weeds often cause failure during establishment of forest reproduction.

MAMMALS

Most potential mammal damage can be prevented by habitat alteration. Preferred pocket gopher forage, for example, is held back by overstory canopy (Barnes 1974, 1978). Hiding and thermal cover alteration can affect ungulate use and movement. Browse preference studies are inconclusive, although the typical abundance of natural seedlings can contribute to successful forest reproduction in areas where tree seedlings provide food sources.

INSECTS

Minimizing stress and featuring diversity are keys to insect damage management. Insect pests are opportunistic when weakened hosts are present. Shelterwoods promote mesic, structurally-stratified conditions during the regeneration period.

FUNGI

Where rhizomorph or root contact is the primary path of disease spread, group and strip shelterwood methods may provide adequate barriers.

DWARF MISTLETOE

Dwarf mistletoe can be effectively prevented from the new generation by timely removal of infected overwood (Hadfield and Russell 1978).

WEEDS

Understanding the likely responses of weeds to given disturbances is fundamental to successful regeneration. Even such vigorous competitors as long-stolon sedge (Carex pennsylvanica) can be effectively managed by anticipating responses and gaining competitive advantage for seedlings during the critical establishment period.

All of the pests which dictate success or ruin of forest stands can be effectively kept within tolerable limits through judicious silvicultural practices. Even in mountain pine beetle epidemics, evidence on the Deschutes National Forest supports shelterwood strategies to create resistant stands. Recognition and anticipation of forest pests is the first step to successful management. The need for recommendation and monitoring of effective site-specific prescriptions again challenges silviculturists' cleverness.

Seed Periodicity and Fates

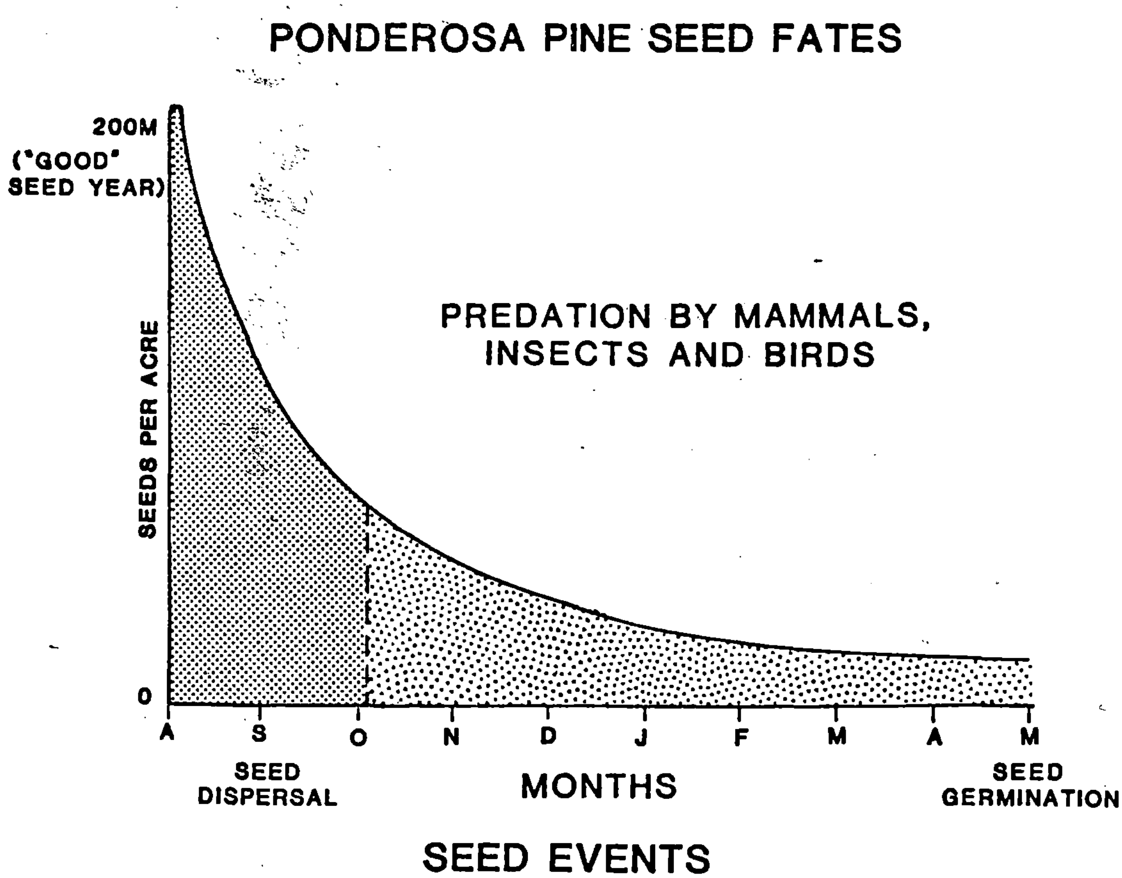
Periodicity of tree seed crops has been a long-recognized phenomenon (Daniel, Helms, and Baker 1969). Accompanying episodic regeneration (Franklin and Debell 1973) provides some degree of predictability. Daniel, Helms, and Baker list nine "essential conclusions" about periodicity and fruitfulness:

1. A good seed year for one species is not necessarily good for another.
2. Crop variation is wide in some species, narrow in others.
3. Some species have short cycles; others have long cycles.
4. Total crop failures are rare.
5. Uniformly good crops over a region are rare.
6. On a local basis, good crops are found on very large areas.
7. Some trees are barren in the best seed years; some bear seeds in years of crop failure.
8. There is more seed crop variation in stands than in isolated trees.
9. Good seed years cannot be predicted before flower buds are formed.

Rather than allow unpredictabilities associated with seed crop production to be barriers to natural reforestation, one can apply the above conclusions, along with active monitoring, to cleverly narrow the uncertainties to a range of probabilities. For example, in pines, one can differentiate proportions of vegetative and reproductive primordia nearly two years in advance of cone maturation. Minimally, then, it can be determined if site preparation is not warranted about two years hence. With other species, lead time is almost a year.

Insects are the most destructive agents to fruits and seeds. Predation by insects is inversely proportional to cone abundance (Fowells 1965). Fungi and bacteria also affect seed production by attacking the fruits of trees (Schopmeyer 1974). After cones develop,

mammals and birds become primary limiters to availability of seed. Seed-eating mammal populations typically increase following seed abundance of the preceding year (Schmidt and Shearer 1971). These agents, in consort with adverse weather and physiological factors, cause seed crops to decline precipitously.



(adapted from Schmidt and Shearer 1971)

FIGURE 12

Fowells (1965) has compiled details of seed periodicity, dispersal, predation, and ages at which seed production begins in United States forest trees. Minore (1979) addresses seed production, dissemination, crop size, crop frequency, soundness, flight, durability, longevity, germination and stratification requirements of Northwestern trees. Such information should be tempered by observations that amounts of seed needed for natural reproduction are considerably less than those needed to make collectable crops for artificial regeneration purposes (Jaszkowski, personal communication).

Advantages and Disadvantages of Shelterwood Systems

ADVANTAGES

FLEXIBILITY	1.	Flexibility allows creation of any desired regeneration micro-environment (White and Graham 1978).
	2.	Constraints of current standard practice are avoided (White and Graham 1978).
	3.	Planting limitations due to elevation and topographic position (snowmelt, accessibility re: storage and handling) are removed.
	4.	Seed cut size is not administratively limited.
RISK MANAGEMENT	1.	Risk is reduced in that the main harvest cuttings follow, rather than precede, establishment of reproduction.
	2.	Continued, local seed source reduces risk on known difficult-to-regenerate sites.
	3.	Provides protection from excesses of temperature, insolation, and wind.
	4.	Pioneer competitors are retarded.
	5.	Pocket gopher invasion is impeded.
	6.	Dependency on herbicides during the establishment period is reduced.
	7.	Soil erosion and dessication can be minimized.
	8.	Associated mesic conditions stimulate decomposition.
	9.	Fuel drying is retarded.
	10.	High water table areas can be reforested.

Y I E L D S	1. Continuous site occupancy is maintained by establishment of two levels of growing stock. 2. Average rotation length can be shortened because one generation overlaps into the next.
E C O N O M I C S	1. Desirable financial aspects (Starker 1970): a. Recovery of part of the investment earlier in the rotation. b. Allows prompt salvage. c. Reduces the financial waiting period (to final harvest). d. Concentrates growth on the best trees. e. Reduces growing stock volume, hence reduces <u>ad valorum</u> tax exposure. 2. Planting expenses and risks are avoided. 3. Early road construction facilitates selection of special products.
G E N E T I C S	1. Genetic gains can result without special measures. 2. Gene pool preservation is facilitated. 3. On-site seed source is guaranteed. 4. Mixing of naturals with improved stock enhances genetic gain.

DISADVANTAGES

COMPLEXITY

1. Timing of seed cut with seed availability and timing of removal cuts to prevent understory stagnation is difficult to coordinate.
2. Execution complexity requires high skill level.
3. Application is difficult in stands with high dwarf mistletoe levels.
4. Multiple entries may be required during the regeneration period.
5. Density control may be relatively more difficult.
6. Composition control is not absolute.
7. Irregular distribution of stocking may result.
8. Herbicide applications are limited by overstory.
9. Residuals may be harmed by fire applications.
10. Seed trees must be windfirm.
11. USDA Forest Service reporting procedures and forms do not credit natural regeneration accomplishments.

YIELDS

1. Understory damage can result from felling and skidding.
2. Establishment period may be relatively long.

ECONOMICS

1. Layout and markings costs are relatively high.
2. Felling and yarding costs are relatively high.
3. Poor trees are cut before best trees, making the system less financially attractive in the short run.

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1. Inbreeding depression is enhanced.

Successful Shelterwood Management in Area IV

A number of important factors have been identified in formulating natural regeneration prediction models:

1. a good seed crop
2. a mineral-soil seed bed
3. no more than a sparse population of seed-eating rodents
4. no competing vegetation
5. one or more favorable growing seasons immediately following seedfall

(adapted from Roy 1983)

or

1. adequate seed produced and distributed over area
2. soil warm and wet enough in spring to allow germination
3. weather conditions which minimize frost-heaving
4. soil-air interface temperatures which are moderate
5. summer drought survival
6. survival from depredation by animals and disease
7. favorable physical conditions (duff, slash, etc.)

(adapted from Cochran 1973a, 1977).

These factors, if viewed as sets of independent variables, would each need to coincide within the same precise time frame for natural reproduction to occur (USDA Forest Service, Ochoco National Forest 1975). Silviculturists can deal with the exigencies of nature by influencing the types, timings, intensities, and extents of ecosystem disturbances relative to growing space, site preparation, and seed source. Silviculturists can cleverly affect timing of seed dispersal relative to germination and establishment environments for even the most infrequent and unpredictable seed producers, e.g. ponderosa pines (Barrett 1979). Recognizing that some seeds are produced every year, and that species diversity enhances adequate seed crop potential (Haig, Davis, and Weidman 1941), there is considerable flexibility in

natural reproduction composition adjustments. Overstory densities correlate positively (to a point) to seed quantities in shelterwoods (Shearer and Schmidt 1970). Overstory composition (also to a point) correlates to probable understory makeup (Scott, personal communication).

To illustrate complexities inherent in timing and intensity, consider a mixed conifer stand of ponderosa pine and white fir (<u>Abies concolor</u>):

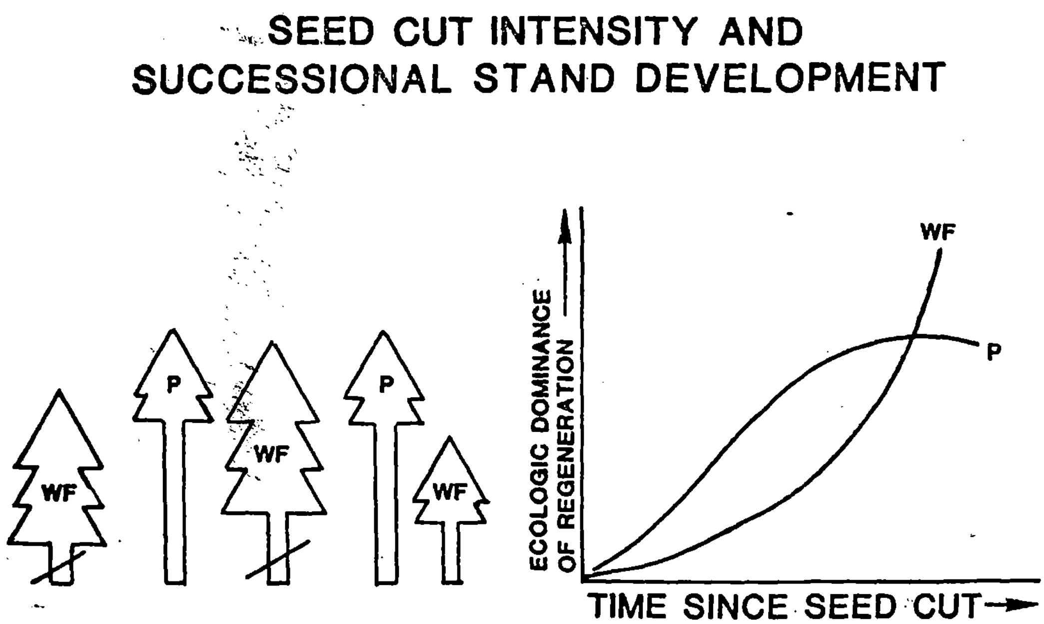

FIGURE 13a

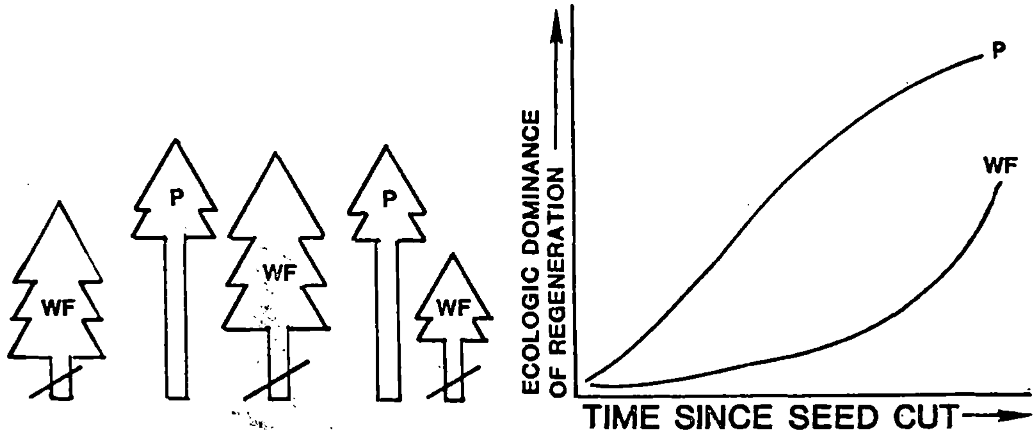

FIGURE 13b

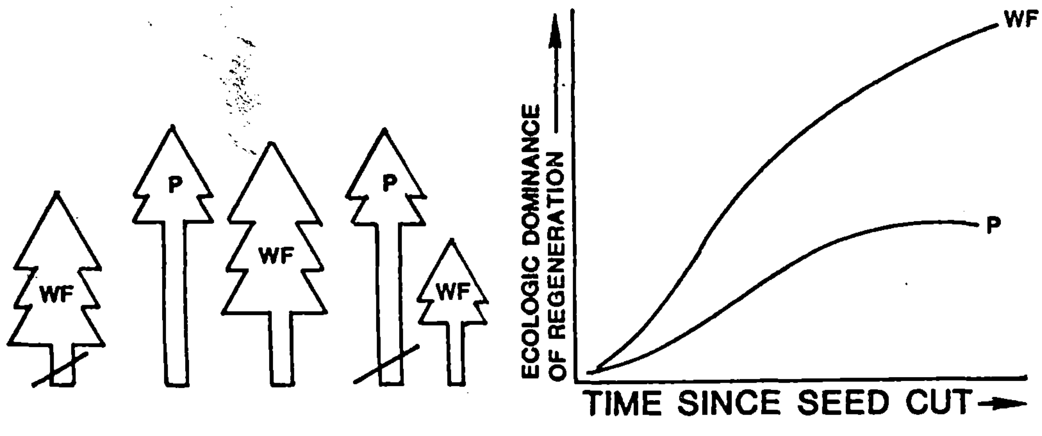

FIGURE 13c

Note how intensities of cuts into each component (given variation in seed periodicities between species) could result in different early-successional results.

Seidel and Cooley (1974) and Seidel (1979b) recommend a range of seed tree basal areas in grand fir (*Abies grandis*), Shasta red fir (*Abies magnifica* var. *shastensis*), and mountain hemlock (*Tsuga mertensiana*) within a predictable time context of five years. Cochran (1969a, 1973a, 1977) points out the sequence of events that must occur if natural regeneration is to be successful in lodgepole pine ecosystems. Barrett, Tornbom, and Sassaman (1976) demonstrated clever applications of successful removal cuts over advanced ponderosa pine regeneration. Dahms and Barrett (1975) quantified seed crop needs and periodicities in south-central Oregon. Martin (personal communication) and Agee (personal communication) suggest multiple burnings on sites where competitors have stored seed in the forest floor. By burning snowbrush ceanothus (*Ceanothus velutinus*) and golden chinquapin (*Castanopsis chrysophylla*) after successive germination and sprouting following initial space provision by fire, for example, one may provide a durable, competition-free environment for early growth of desirable species. These scientists' benchmark studies have led many to adopt the demonstrated practices.

The research base, as well as local experience, can provide a powerful position from which to extend applications of shelterwood systems. Finally, skill in creating favorable seedling environments, as evidenced by recent south-central Oregon artificial regeneration successes, has direct applicability to natural regeneration.

CASE STUDIES

This section samples little-known information about natural regeneration and shelterwood systems. The importance of cleverness (Scott, personal communication), or imagination (Daniel, personal communication), for example, is seldom recorded. Adaptations of flexible shelterwood variants, after careful observation and understanding of natural reponses to disturbance, are therefore highlighted in this report. Another key factor to success, although seldom recognized, is the need for a positive attitude during prescription and implementation phases of reforestation projects. Without it, reforestation projects are doomed. Cooperation between colleagues and clients of different disciplines and with diverse goals can have a synergistic effect that is little recognized in the literature. Lastly, management direction, although often overlooked in research publications, can be shown as the foundation of successful reforestation.

CLEVERNESS AND FLEXIBILITY

This is the challenge to modern silviculturists: to draw upon time-proven systems and apply the broad array of tools and methods represented in classical silviculture to accomodate the changing desires of today's landowners. To respond favorably to this challenge requires a closeness to the land that has characterized European forestry for centuries.

Torba (1985) developed a certification prescription (document required by the USDA Forest Service to be successfully developed, presented, and defended prior to certification as an agency silviculturist) which demonstrates studied observation and clear portrayal of risk management in a clever response to management direction. Essentially, study of nearby past disturbances led to confident predictions of stand development. Management directed not only adherence to all federal policies and laws, but also maximization of net present worth and enhancement of future flexibility. A shelterwood system was chosen for the certification stand. The stand is representative of a plant association comprising more than twenty-five thousand acres on the Klamath Ranger District of south-central Oregon.

Similar observations lent credence to the shelterwood regeneration portion of a certification prescription (Horton 1980) five years earlier in the same plant association about twelve miles distant from Torba's certification stand. At the time, cost-effectiveness was not a featured part of management objectives. However, flexibility was recognized as being a "must" criteria in management direction. In this prescription, past partial cuttings near the certification stand revealed various (although patterned) responses to intensities of logging. Careful field study revealed response patterns which allowed the regeneration prescription to imitate desired natural conditions.

Wagner (1980) recorded detailed observations of edge effect on a Pacific silver fir (<u>Abies amabilis</u>) clearcut. His measurements provide insights into how various species of various tolerances

perform relative to various edges. Application of such insights is not limited to the central Washington Cascades study area, but could be used by silviculturists in other regions. Research location is much less important than the concepts derived. As this report concentrates on south-central Oregon, the findings outlined have important implications for silviculture in the greater Pacific Northwest.

POSITIVE ATTITUDE

Barrett (1976) offers one of the first case studies that identifies good communication--an element which fosters positive attitude. By successfully removing a 24,000-board-feet-per-acre overstory and preserving 180 crop trees per acre over three-fourths of the area, confidence was relayed to those who thought that such removal cuts would cause extensive damage to understories.

Drawing upon Barrett's work, a similar prescription was applied on a mixed conifer site in southern Oregon (Horton 1984a.) After a removal cut of 25,000 board feet per acre, the stand was left with (density adjustment problems of) more than 800 trees per acre. During interviews with the responsible sale officer and loggers, it became clear that mutually agreed-upon and understood objectives, along with "can do" attitudes, contributed most significantly to the project's success. The prosperous outcome of this treatment is evident in a (now) thinned sapling-pole, mixed conifer stand. The stand has about a fifteen year head start on an adjacent ponderosa pine plantation which was planted (about five years prior to the removal cut) after clearcutting .

COOPERATION

The forgoing examples also show the need for cooperation between all of the people involved in sophisticated silvicultural methods. This concept is most clearly illustrated in continuing combined efforts of Gary J. Petersen, District Silviculturist, and Francis R. Mohr, Fuels Management Specialist (Petersen and Mohr 1984). By working closely together both in planning and in the field, they have cleverly, successfully, and repeatedly captured seed crops on white fir sites in northeastern Oregon. Savings of more than a quarter of a million dollars annually on the Wallowa-Whitman National Forest are being realized by prescribed burning prior to seed fall. Current cooperative efforts aim at reducing costs even further as perceived limitations are tested and extended.

Personal observation of these colleagues at work in the field together leaves the writer convinced that teamwork of this order can accomplish what had been thought to be impractical, if not foolhardy--successful underburns in true fir stands. Working together to achieve optimum flame lengths, rates of spread, and residence times for seed bed preparation at the desired times exemplifies the highest levels of cooperative silvicultural practice.

MANAGEMENT DIRECTION

This part of successful natural regeneration planning is acknowledged throughout the literature (Munger 1912, Franklin and Debell 1973). As the most important prescription element, it is further featured in this case studies summary.

Seattle City Light's (municipal electric utility company) accomplished management of the Cedar River Watershed demonstrates sixty years of minimum reforestation investments, resulting in the longest continuous reliance on natural regeneration in the Pacific Northwest (Scott, personal communication). Planting constitutes less than three percent of their reforestation workload. Management direction, in this example, is in the form of little or no budget for reforestation.

Similarly, but representing a dramatic shift in strategies, the Deschutes and Winema National Forests of south-central Oregon have recently directed natural regeneration to be featured in lodgepole pine reforestation during the current extensive mountain pine beetle epidemic. As new economies become manifest in lodgepole pine management, accelerated adoption of natural regeneration practices into other plant associations of south-central Oregon is also occurring.

All of these "human" factors play as important a role in the success of natural reforestation as biological principles. Attention to intangible distinctions of natural regeneration case histories enables foresters to see beyond the barriers to success.

CONCLUSIONS

All south-central Oregon species are capable of being reproduced by shelterwood methods. No species requires a specific silvicultural method. Delays in timing of the new generation's beginning cause greatest anxiety. Delays can be managed by telescoping one generation into the next, keeping the best trees on-site. Cleverness in manipulating the shelterwood variables of timing, intensity, and extent determines success or failure. Of these variables, timing is most critical. Increased attention and research into timing will yield significant payoffs.

Many forest stands in south-central Oregon have been high-graded, neglected, restricted from treatment, or are so decadent that shelterwood systems (even with preparatory cuts to improve stand conditions) would be ill-advised. There is more evidence of shelterwood environments by default having produced desirable results than there is in purposeful application of shelterwood methods to achieve desired forest conditions. By embracing natural systems in south-central Oregon, forest officers might risk over-enthusiastic implementation in the same manner that has occurred with artificial systems. Current technology provides a backup.

Most stands exhibit clues indicating what a given set of disturbances, at given intensities, at given times, will likely produce. Silviculturists are challenged to read the ecological stories presented by their stands. Seeming conflicting results

reflect complexities relative to variety of sequences and disturbances. Much information relating to fundamental "why" questions has yet to be revealed. Foresters can leave written, as well as on-the-ground, records of trials. Pacific Northwest foresters may be pioneers in adapting modern technology to wild forest stands, but the silvicultural methods used by them are centuries old.

Advance regeneration management has wider applicability. South-central Oregon foresters wisely consider retention of advance reproduction, including trees with light to moderate dwarfmistletoe infections, before investing in plantation establishment. Group shelterwood treatments, with groups emanating from from stocked clumps, extend capabilities in managing advance regeneration.

Planting technology is certain, but expensive. Consideration of shelterwood systems in analyses of least-cost prescription alternatives would tend to balance the current silvicultural approach to reforestation in south-central Oregon. Shelterwood systems can avoid or reduce seedling production, storage, and handling costs. Shelterwoods mitigate severities of temperature and moisture. Flexibility, while avoiding drawbacks of current standard practices, remains the strongest argument for shelterwood systems. A shift toward shelterwood systems represents greater sophistication of forest management programs.

VALUE OF FINDINGS AND CONCLUSIONS

Information presented in this report provides a springboard for adaptation to current and projected management environments. A new method for evaluating reforestation time and dollar trade-offs, for example, helps forest managers determine the cost of waiting for seed crops. Yield and genetic relationships are illuminated so that commonly-held myths about decreased productivities and incompatibilities are dismissed. The selected annotated bibliography provides the first public comprehensive review of shelterwood literature since 1965 (Gould 1965). Electronic query by keywords allows access to specific research reports quickly. The paper justifies changing USDA Forest Service attainment reporting forms in order to foster natural regeneration technology. Examples showing clever applications of flexible systems lend confidence to future cost-effective forest management.

Need for further study of seed production physiology is revealed. Re-activation of research in seed predation control is also warranted by the evidence. Renewal of direct seeding research might provide less expensive backup capability to natural reproduction efforts. These research areas were essentially abandoned when pesticide restrictions were increased and when high plantation survival rates began to be achieved (1960's and 1970's).

Expanded application of natural regeneration systems in the four national forests of south-central Oregon by ten percent would result in savings of at least $100,000 annually. A balanced approach of fifty percent natural regeneration and fifty percent plantation investments would yield annual savings of about $500,000. Natural regeneration systems could contribute positive present net values in stands where artificial systems currently cause disinvestments.

RECOMMENDATIONS

1. Expand shelterwood system applications.
2. Provide management direction that allows flexibility in prescription alternative development.
3. Require a least-cost alternative in prescription formulation.
4. Reward cleverness.
5. Direct research toward seed periodicity and seed depredation control.
6. Change attainment reporting forms to credit natural reforestation.
7. Encourage trends toward shorter harvest contract periods.
8. Encourage end result (stewardship) reforestation contracts.
9. Encourage activities which integrate harvest and reforestation.
10. Encourage improvement cuttings and thinnings in immature stands to enhance future natural regeneration potential.
11. Strive for balance. A reminder from Smith (1979): "The shelterwood system is a good idea and its time appears to have come. All good ideas wait in the wings and come on stage at the appropriate time. Then they get over-done and run into the ground. I have been around long enough to get the eerie feeling that American forestry and National Forest Administration have been through such episodes before."

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